WHITE PAPER

AirShield.

A commercially viable solution to social distancing for air travel

TEAGUE

Contents.

Introduction.

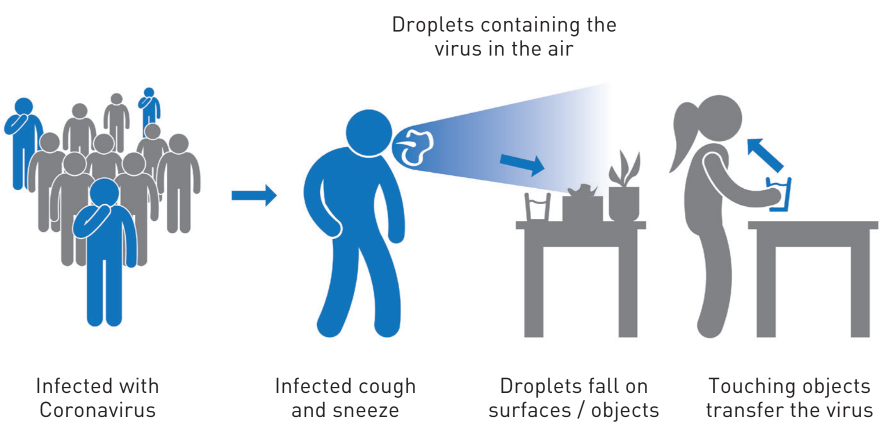
Social distancing is proven to be one of the most effective methods of combatting the spread of highly contagious viruses like SARS-CoV-2 that causes COVID-19[1]. While many environments are easily adapted to maintain a safe 2m distance between people, aircraft cabins, with a fixed layout and dependence on passenger density for economic viability, require special considerations to ensure passenger safety. Recent solutions have focused on decreased passenger capacity, the introduction of immovable barriers between passengers, or a combination of both. For an industry already battered by this pandemic, the decrease of passenger revenue or increased costs in development, certification, and added weight required by these solutions is difficult to bear. One alternative solution is to repurpose the gasper system already onboard all aircraft to create an invisible and effective curtain of air to dampen the spread of contagions in the cabin.

Background.

VIRUS TRANSMISSION

Transmission Vectors
Viruses are spread via tiny fluid globules. These particles are passed person to person through the air or by direct contact on a common surface. Both of these 'transmission vectors' then require the globules to enter the mouth or nose of the other passenger to be transferred.

Social distancing limits spread via both vectors by spreading people farther apart than the fluid particles are likely to travel through the air, and by reducing the number of common surfaces people come in contact with.



Recent guidance from the CDC suggests that the Coronavirus that causes COVID-19 is not easily spread via surfaces, and prevention should focus on respiratory transmission.[2]

Respiratory Transmission
Respiratory spread occurs in two forms, aerosol and droplet transmission, depending on the size of the fluid droplet.

Aerosol Transmission
Aerosols, droplets smaller than 5um in diameter, are buoyant or 'lighter than air.' These lighter particles tend to hang in the air for long periods, and the movement of air around them dominates their motion and range.

Droplet Transmission
Droplet transmission occurs with particles larger than 5um in diameter. These heavier droplets tend to fall out of the air relatively quickly. Classic projectile motion equations can describe the general motion and distance traveled by these droplets.

SARS-CoV-2
Continued guidance from the WHO and CDC suggests that the coronavirus that causes COVID-19 is spread through heavier than air droplet transmission, [3].

The Simple Projectile analysis predicts that particle ejected via sneeze at 4.5m/s[4] at an angle of 45deg could travel ~2m before falling below mouth or nose height. Hence the standard social distancing guidance of 2m spacing.

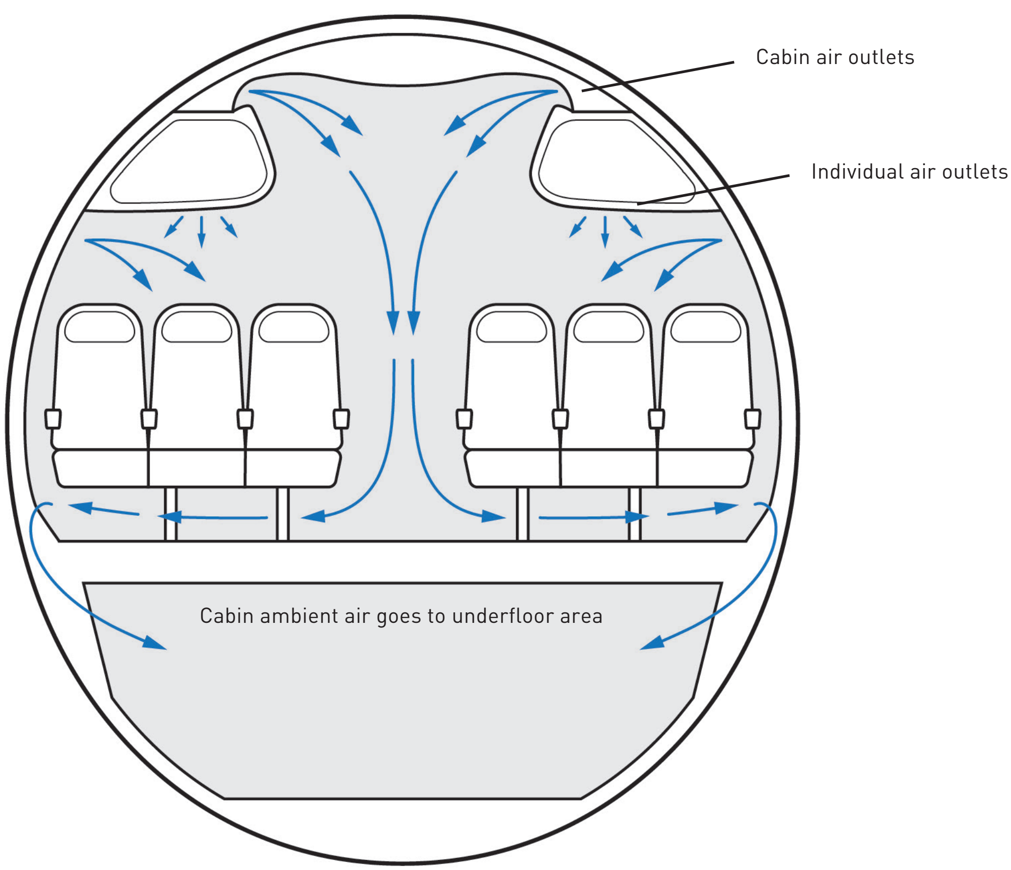
However, recent studies[5] have shown that strong air currents can significantly impact the trajectory of and distance traveled by respiratory droplets in the air. The well-publicized[6] case of a restaurant in Guangzhou, China[7] shows that in a poorly ventilated space, particles influenced by the airflow of a strong air conditioner infected diners spread well over 2m apart.

AIRCRAFT CABIN AIR ENVIRONMENT

Cabin Air Movement

Aircraft cabins are well-engineered and highly controlled interior environments. The cabin's environmental control system (ECS) creates a predictable spiral flow of air inside the passenger area. Air flows from the ceiling to floor, reducing the potential for transmission forward or aft in the cabin. Moreover, flow rates are high and not conducive to droplet spread in the same way as in other indoor environments[8].

AIR CIRCULATION IN A TYPICAL SINGLE-DECK AIRCRAFT

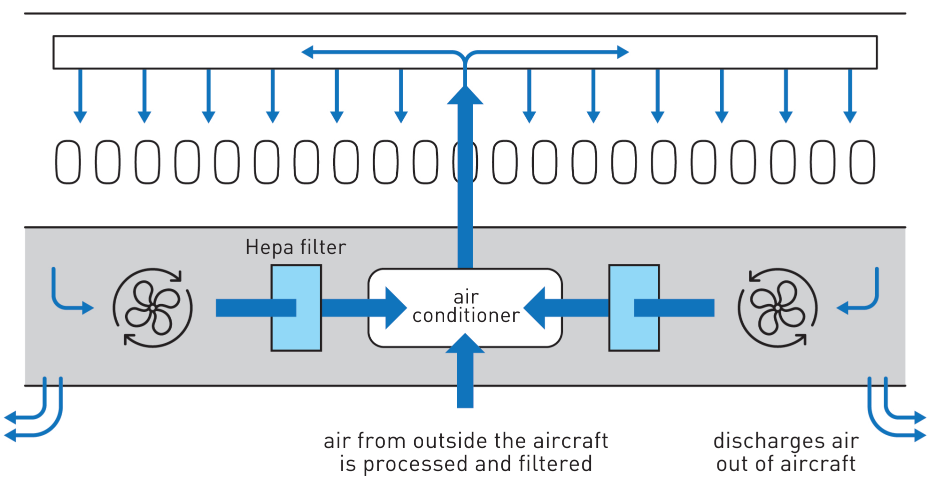


Filtration and Refreshment

Onboard High-Efficiency Particulate Air (HEPA) filters on modern aircraft continuously clean cabin air—removing 99.97% of particles and contagions larger than 3um[9]. In addition, federal regulations[10] mandate that the cabin air is continually refreshed with air from outside the plane, ensuring that the air in the cabin is approximately a 50/50 mix of fresh air from outside and recirculated filtered air. The result is that the cabin air is entirely refreshed every two to three minutes[11].

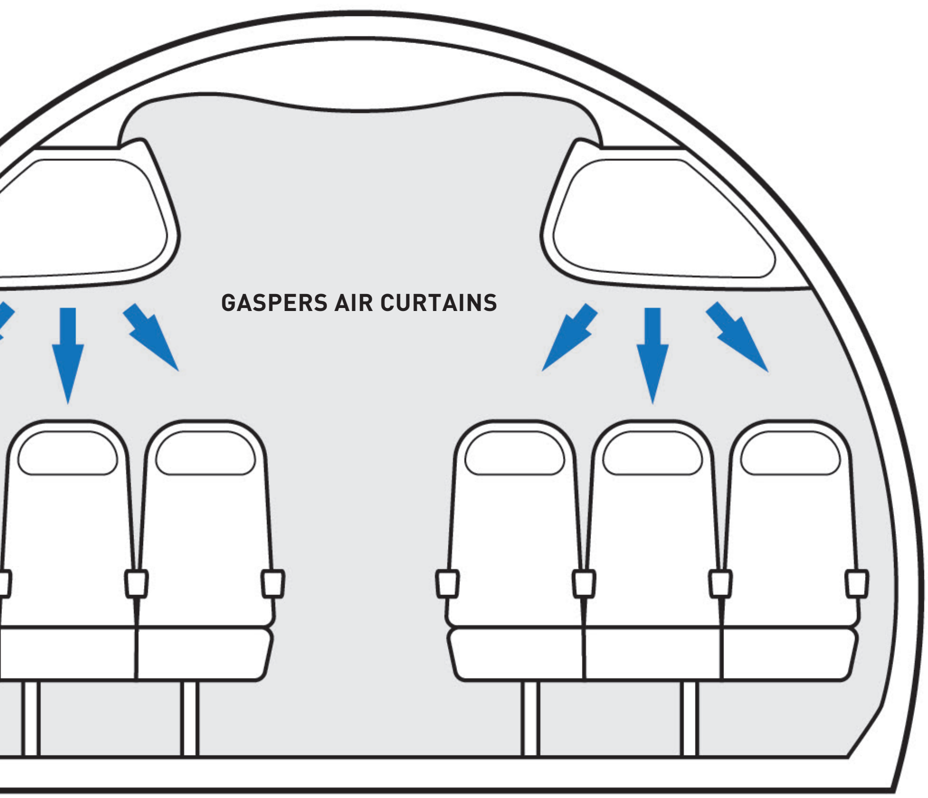
In contrast to restaurants and other interior environments, the existing design of aircraft ECS systems effectively limits large scale spread of coronavirus[12].

THE CABIN AIR IS CONSTANTLY FLOWING. THE CABIN FLOWS FROM THE CEILING TO THE FLOOR. THE AIR IN THE SIRCRAFT DOES NOT STAY STAGNANT.



Effect of Gaspers

Previous research indicates that the personal air gaspers above each seat have the potential to offer additional protection against local virus spread between neighboring passengers[13], [14]. The downward flow of air from the gasper nozzles helps to redirect respiratory particles either onto adjacent surfaces or into the cabin flow of air at the floor to be filtered.



Room for Improvement

Despite these potential benefits, the primary intent of the gasper system is passenger comfort, not protection. To improve the effectiveness of gasper airflow to mitigate the spread of contagions, the shape and position of the air jet must be optimized for this purpose, and local control of airflow eliminated.

Solution.

EFFICIENT AIR ENVIRONMENT MANAGEMENT

Despite tight passenger density, aircraft cabins have been shown to relatively effective at mitigating the spread of particles and disease compared to other forms of transportation and interior environments.

Aircraft are designed with a well-conceived airflow and filtration scheme.

The seating layout limits the amount of face to face interactions between passengers while seat backs provide physical barriers against transmission fore and aft. Studies suggest that airflow from the gaspers can further reduce the risk of spread, though this system is not optimized for the task.

AirShield is a proposed solution to improve the effectiveness of the gasper air system and further increasing the safety of the cabin environment.

AIRSHIELD

AirShield is a low weight, easily retrofittable nozzle that uses gasper air supply to create an invisible curtain of air between passengers.

The shape and speed of the air created by **AirShield** is optimized to deflect particles emitted from one passenger downward, safely away from other passengers' noses and mouth—either toward existing physical barriers or to be extracted and filtered by the existing aircraft air systems.

Aircraft Integration

The **AirShield** concept is intended to be easily integrated into existing cabin architecture, with each implementation customized based on PSU geometry, cabin styling, and seating layout. The adapters are uniquely suited to be produced by 3D printing to enable rapid production and customization as well as to create internal baffling and ducting features for improved airflow.

Solution Concepts

The final form of the product will be customized to suit specific aircraft and airline cabin designs.

Using **AirShield**, the air environment can be effectively managed in the Aircraft Cabin, much more than in most public environments, which, once communicated and understood, should be very reassuring for the travelling public.

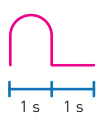
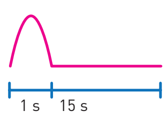
Analysis.

Side by side Computational Fluid Dynamics (CFD) analysis of a passenger seated in a representative single-aisle aircraft cabin with and without air shield demonstrates that the concept effectively redirects respiratory emissions to the floor.

AIR FLOW INPUTS

Respiration

Research has shown that breathing, coughing, and sneezing each emit particles at unique speeds and durations.

Event	Max Velocity	Transient Cycle	Comments	Source
Breathing / talking	1.5m/s		Regular, slow, continuous phased release.	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3613375/
Cough	3m/s		Assuming a controlled cough. Could be more than one event	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3335026/
Sneeze	4.5m/s		An explosive one-off event, high velocities	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3613375/

Gasper Flow

Research suggests a gasper flow rate of between 0.0015 m^3/s and 0.0029 m^3/s[15]. This means an air curtain measuring 0.5m wide by 2mm long would result in airspeed of 1.5m/s.

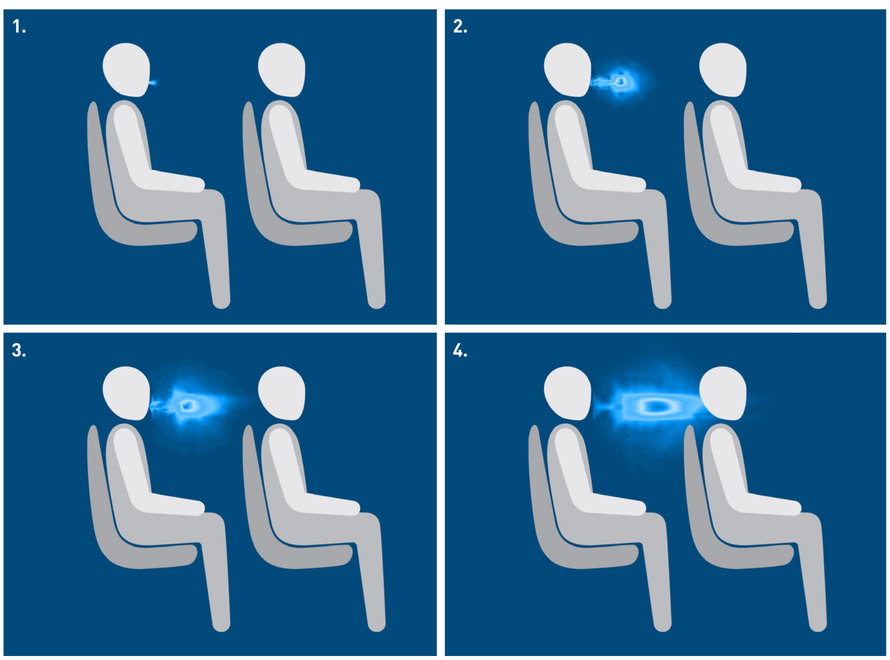
PROOF OF CONCEPT ANALYSIS

Simulation Description
A three-dimensional simulation was done using a fluid volume capturing two rows of seats on the starboard side of a single-aisle aircraft.

For the analysis, the AirShield with a constant flow rate of 0.0015m^3/s at a velocity of 1.5 m/s. A single breath is captured as a transient event with a burst of air from the passenger's mouth at a velocity of 15m/s.

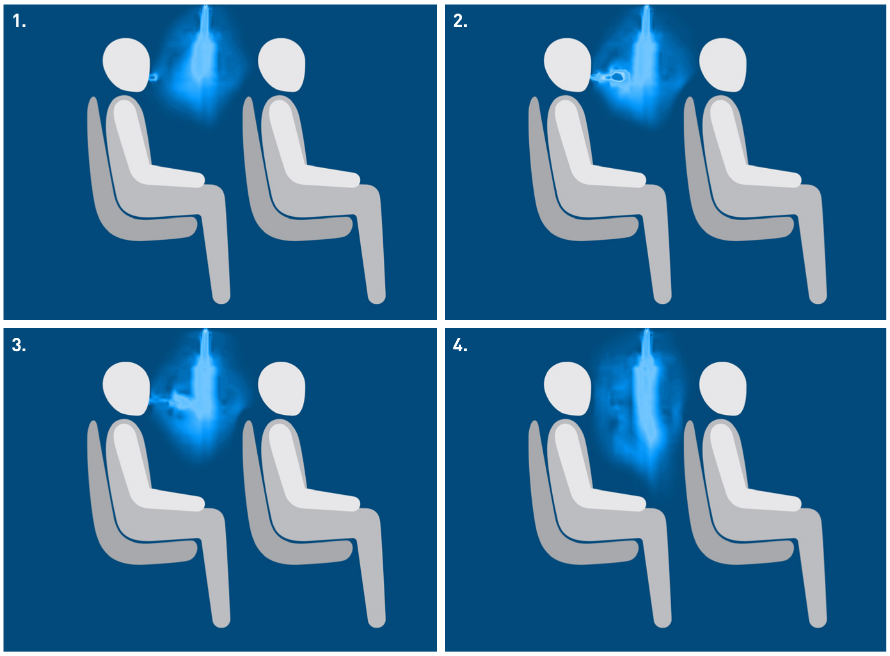
The simplified analysis does not account for global cabin air motion created by the ECS system.

Baseline Result – No AirShield
A sequence of images from the baseline analysis shows a single breath moving unobstructed across the forward seatback.



With AirShield

A sequence of images showing the effect on a single breath after the introduction of the **AirShield**.



Conclusion.

The Covid-19 pandemic has had a profound impact on the aviation industry. While airlines have already taken significant strides to ensure the safety of their passengers, the fixed seating layout of an aircraft makes the recommended social distancing difficult without reducing the number of passengers on board. As the world begins to reopen, the industry will require a more robust and long-term approach to protect passenger safety without eliminating passenger density and associated revenues. The **AirShield** system is a practical solution that utilizes existing cabin air systems to virtual separate each passenger by a curtain of air.

AirShield is a simple adapter designed to integrate into the existing aircraft gasper system. Using Computational Fluid Dynamic analysis, the **AirShield** adapter is engineered to transform the gasper airflow into an optimally sculpted blade of air around each passenger. Building on the already robust air handling and cleaning system onboard the aircraft, **AirShield** safely redirects respiratory particles away from other passengers' noses and mouth downwards, towards the lower extraction grills to be filtered.

AirShield is intended for customization. Individual units can be uniquely engineered per aircraft type, class layout, or specific seating row. The adaptors are designed to be 3D printed from aerospace approved material to allow an optimized shape, rapid production, and flexibility to install on to any Aircraft.

FURTHER DEVELOPMENT

AirShield has the potential to be an effective, quick, and real solution to promote the safety and peace of mind of the flying public. With the proof of concept established, there is a clear roadmap for further development ahead of certification and deployment on aircraft.

1. **Further Validation By CFD**
    a. Expand to including full cross-section, multiple seating rows, and representative cabin airflow
    b. Evaluate shield airflow parameters relative to breath, cough, and sneeze
    c. Consider accoustic impact on cabin

2. **Design Baseline Airshield Adapter**
    a. Define internal baffling and and flow balancing features
    b. Develop air-jet nozzle geometry to create desired air curtain
    c. Establish aircraft interface and attachment features

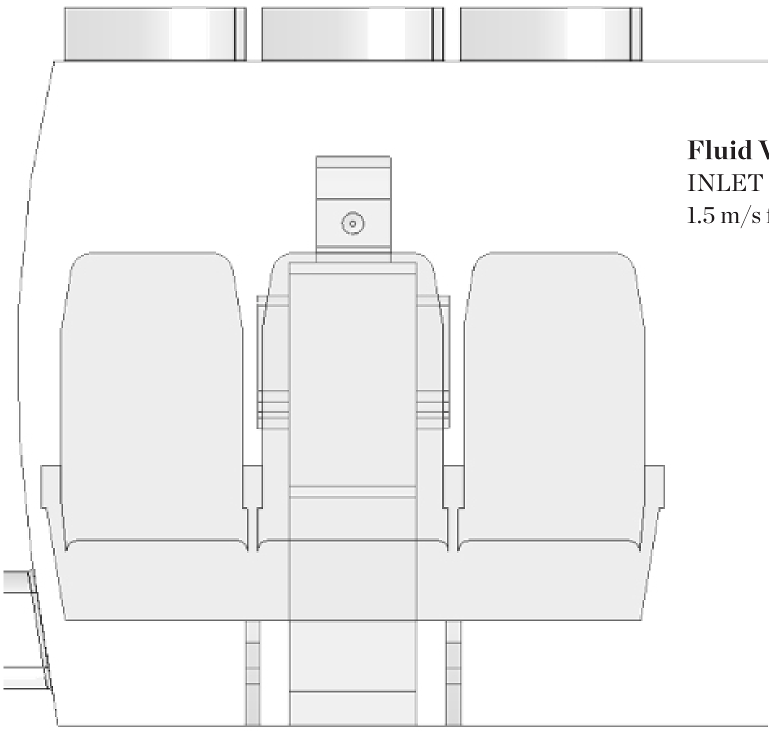
3. **Prototype, Test, Iterate**

Appendix.

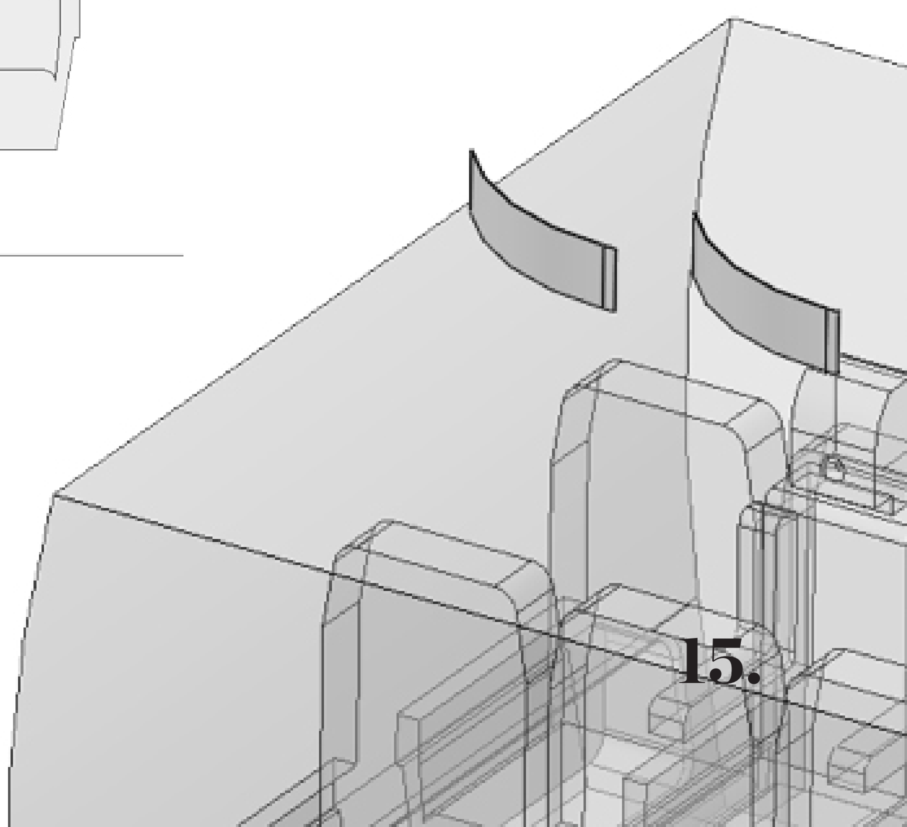
CFD ANALYSIS DETAILS

Setup

INLET – representing air blade
1.5 m/s flow rate
0.5m long x 2mm thick



Fluid Volume
INLET – representing breath
1.5 m/s flow rate

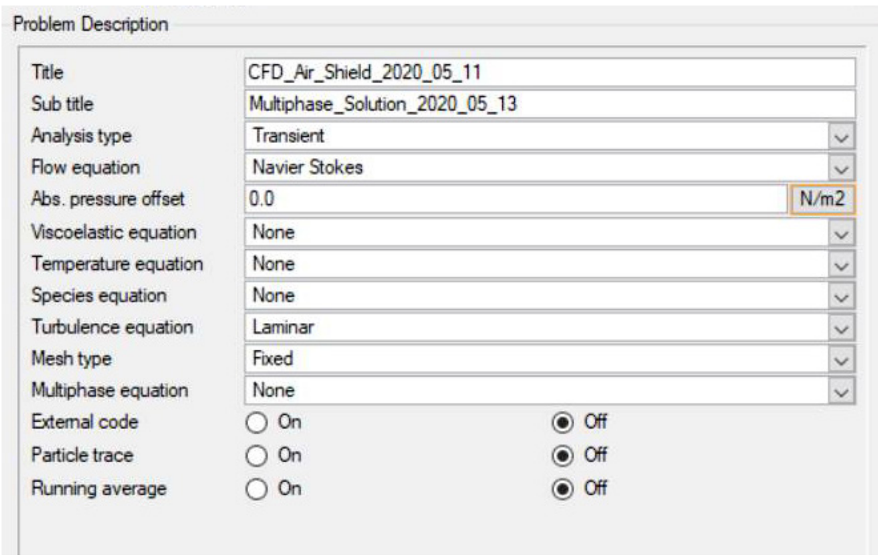


Solver

Altair AcuSolve

Input Settings

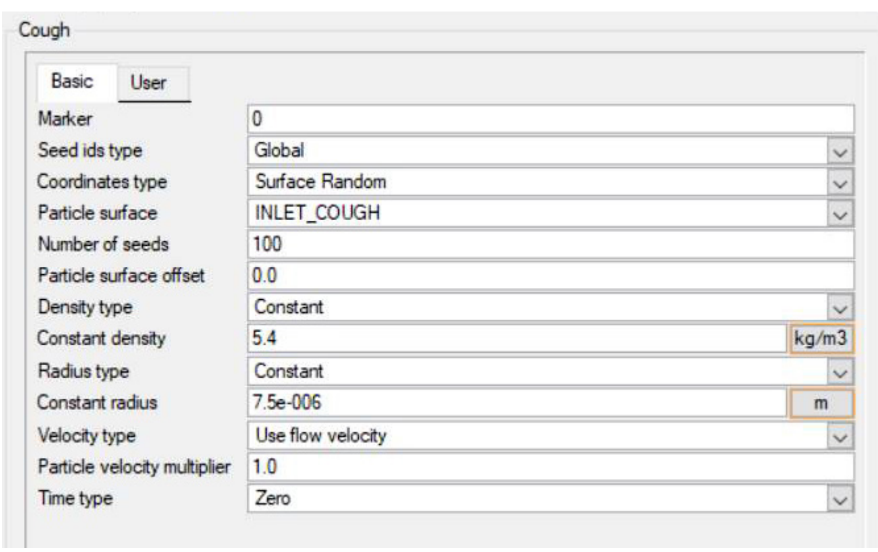
Problem Description



Problem Description

Title	CFD_Air_Shield_2020_05_11
Sub title	Multiphase_Solution_2020_05_13
Analysis type	Transient
Flow equation	Navier Stokes
Abs. pressure offset	0.0 N/m2
Viscoelastic equation	None
Temperature equation	None
Species equation	None
Turbulence equation	Laminar
Mesh type	Fixed
Multiphase equation	None
External code	○ On ◉ Off
Particle trace	○ On ◉ Off
Running average	○ On ◉ Off

Breath Tracing Input



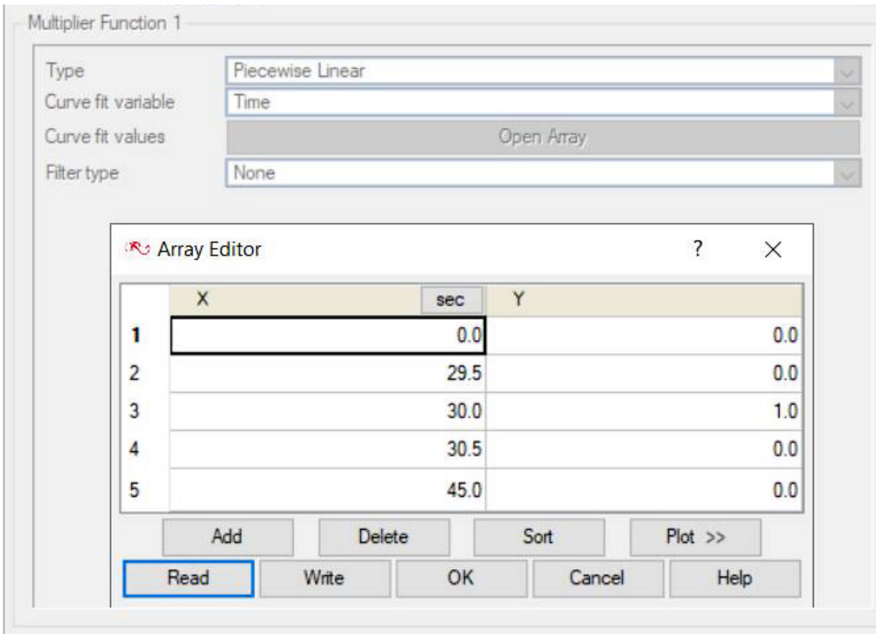
Cough

Basic | User

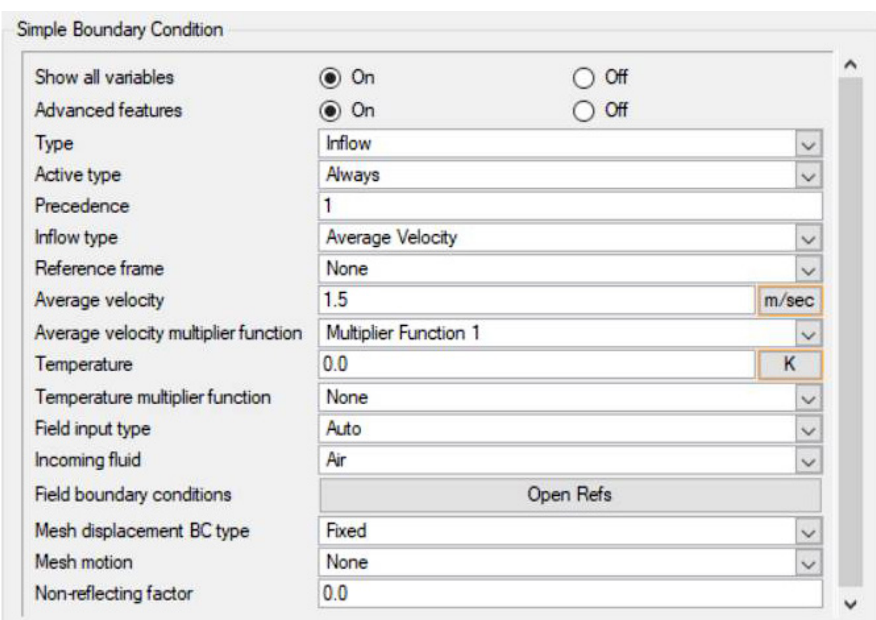
Marker	0
Seed ids type	Global
Coordinates type	Surface Random
Particle surface	INLET_COUGH
Number of seeds	100
Particle surface offset	0.0
Density type	Constant
Constant density	5.4 kg/m3
Radius type	Constant
Constant radius	7.5e-006 m
Velocity type	Use flow velocity
Particle velocity multiplier	1.0
Time type	Zero

Input Settings

Multiplier Function



AirShield Input Definition



References.

[1] https://www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/prevention.html

[2] https://www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/how-covid-spreads.html

[3] https://www.who.int/news-room/commentaries/detail/modes-of-transmission-of-virus-causing-covid-19-implications-for-ipc-precaution-recommendations

[4] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3613375/

[5] https://www.sciencedirect.com/science/article/pii/S0021850220300744?via%3Dihub

[6] https://www.forbes.com/sites/willhorton1/2020/04/22/how-coronavirus-spread-in-one restaurant-shows-why-air-travel-is-safer-than-you-think/#45f7a1541972

[7] https://wwwnc.cdc.gov/eid/article/26/7/20-0764_article#comment

[8] https://www.iata.org/en/pressroom/pr/2020-05-05-01/

[9] https://www.epa.gov/indoor-air-quality-iaq/what-hepa-filter-1

[10] https://www.faa.gov/documentLibrary/media/Advisory_Circular/AC_25-20.pdf

[11] https://www.airbus.com/aircraft/passenger-aircraft/cabin-comfort.html

[12] https://www.pnas.org/content/115/14/3623

[13] https://arc.aiaa.org/doi/pdf/10.2514/1.30272

[14] https://core.ac.uk/download/pdf/10652874.pdf

[15] https://engineering.purdue.edu/~yanchen/paper/2016-15.pdf

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